1,180,762

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,180,762

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COMPLETE SPECIFICATION

Improvements in and relating to non-magnetic alloys and balance springs.

We, SOCIETE METALLURGIQUE D'IMPHY, a French corporate body, of 84 rue de Lille, Paris 7e, France, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The invention relates to non-magnetic ferro-nickel-chromium alloys and to watch balance springs made from such alloys.

Four well-known parameters define the qualities of a balance spring: the temperature coefficient, the coefficient of isochronism, the position variation and the middle-temperature error. The temperature coefficient is a fundamental parameter describing the sensitivity of the spring to variations in the ambient temperature. The other three parameters will not be described here, since they are not directly relevant to the invention and are well known to horologists.

The temperature coefficient is a function of the thermo-elastic coefficient of the alloy used for making the balance spring, this thermo-elastic coefficient characterising the influence of temperature variations on the modulus of elasticity of the alloy.

When a balance spring is made, one aim is to obtain a zero temperature coefficient, for example by using an alloy having, under the operating conditions of the spring, a zero thermo-elastic coefficient.

It is well known, moreover, that ferro-nickel alloys have an anomalous thermo-elastic coefficient which will be explained with reference to the accompanying Figures 1 to 3.

Figure 1 shows, for a temperature of 50°C, the variation in the thermo-elastic coefficient (x 10^6) and more particularly of the apparent temperature coefficient of the portion module as a function of the percentage by weight of nickel in ferro-nickel alloys.

Figure 2 shows, for a ferro-nickel alloy with 32% nickel, the variation in the thermo-elastic coefficient (x 10^6) with temperature.

Figure 3 is a graph corresponding to that in Figure 1 for an alloy containing 10% by weight of chromium.

Certain alloys with a high nickel content have a thermo-elastic coefficient which is definitely positive in certain temperature ranges, although in general the coefficient is negative.

At a given temperature this thermo-elastic coefficient varies considerably according to the nickel content of the alloy. This variation is illustrated by the curve in Figure 1 for nickel contents ranging approximately from 30 to 70% and for a temperature of 50°C.

For a given nickel content, moreover, the thermo-elastic coefficient varies according to the temperature. This second variation is illustrated by the curve in Figure 2 for an alloy with 32% nickel.

For a given alloy, the thermo-elastic anomaly correlates with the magnetic transformation at the Curie point. More particularly, the temperature at which the absolute value of the thermo-elastic coefficient is zero or very small is generallv little different from the Curie point of the alloy.

Because of the existence of this anomaly, the thermo-elastic coefficient of some ferro-nickel alloys is practically zero, and therefore these alloys can in theory be used for making balance springs. However, they

have two disadvantages for such use. Firstly, the rapid variation in the thermo-elastic coefficient according to the nickel content in the zone corresponding to zero values of this coefficient would require—to give an alloy of given characteristics—a precision of manufacture which is not generally possible in industrial production. This is clear from the curve in Figure 1 where the points with a zero coefficient are point A and B. Also, the mechanical characteristics, more particularly the elastic limit, of these alloys are inadequate.

These two disadvantages can be largely overcome by adding chromium to alloys with a ferro-nickel base. In particular, the thermo-elastic anomaly is attenuated, so that the curve in Figure 1 assumes the appearance of that in Figure 3 after only 10% of chromium has been added.

It is therefore possible to define the ranges in the composition of ferro-nickel chromium alloys which can be produced industrially and which satisfy the requirements for materials from which balance springs are to be made.

An alloy of this type, containing on average, in addition to iron, 32% nickel, 10% chromium, 3.5% tungsten and additions of 0.7% by weight carbon, 0.3% by weight silicon and 1.9% by weight manganese, was produced for use in the clock industry under the name "ELINVAR" (registered trade mark belonging to SOCIETE METALLURGIQUE D'IMPHY).

In view of the correlation between the thermo-elastic anomaly and the magnetic transformation at the Curie point, it was generally agreed that this type of alloy combined a zero thermo-elastic coefficient with fairly marked magnetism. However, while a balance spring made of a material having this combination of features is appropriate for a watch with a mechanical movement, it is not suitable for an electrically operated watch, which requires a balance spring which has a zero temperature coefficient and is non-magnetic.

We have found, contrary to what was previously thought, that ferro-nickel-chromium alloys with additions of desirable quantities of one or more of carbon, silicon, manganese and tungsten, can have a zero or approximately zero thermo-elastic coefficient at the ambient temperature at which they are used, slightly above or slightly below their Curie point. According to the present invention, therefore, we provide a non-magnetic ferro-nickel-chromium alloy, which consists, by weight, of:

26 to 29% nickel,
5 to 8.5% chromium,

together with one or more of the following

0.55 to 0.75% carbon,
0.20 to 0.40% silicon,
0.50 to 2.00% manganese, and
2.50 to 3.50% tungsten,

the balance, apart from unavoidable impurities, being iron.

According to the invention we also provide watch balance springs made from these alloys.

We have tested various alloys having a zero or approximately zero thermo-elastic coefficient at the ambient temperature, near their Curie point. By way of example, an alloy having the following composition by weight can be cited.

Ni	27.4%	Cr	5.7%
W	3.5%	C	0.7%
Si	0.3%	Mn	1.9%

Remainder (apart from impurities) Fe

This alloy has all the properties generally required of materials for balance springs. Also, its Curie point, when it has been annealed, is +29°C,—i.e., very close to the ambient temperature.

In practice, when used, the alloy is at the lower limit of the non-magnetic range. It is not attracted to a magnet.

A conventional alloy for balance springs, on the other hand, would have a Curie point of approximately 100-120°C and would be distinctly attracted to a magnet.

In the embodiment considered, the large drop in the Curie point results from a simultaneous and carefully selected reduction in the nickel and chromium contents by comparison with the contents of approximately 32 and 10% respectively usual in the conventional alloy. This reduction is an important feature of the invention, and it has been found that the nickel and chromium contents of the new group of alloys thus defined must be within the following ranges:

26 to 29% for the nickel
5 to 8.5% for the chromium,

these alloys also including, in a proportion comparable to those in conventional alloys, an addition of one or more of the following elements: carbon, silicon, manganese and/or tungsten. These proportions are (by weight):

0.55 to 0.75% for carbon,
0.20 to 0.40% for silicon,
0.50 to 2.00% for manganese, and
2.50 to 3.50% for tungsten.

It has also been found that a secondary effect of the simultaneous reduction in the nickel and chromium was that the elastic limit of a balance spring made from this new group of alloys could be improved by combining cold working and appropriate thermal treatment.

WHAT WE CLAIM IS:—

1. A non-magnetic ferro-nickel-chromium alloy, which consists, by weight, of:

26 to 29% nickel,

5 to 8.5% chromium,
together with one or more of the following
0.55 to 0.75% carbon,
0.20 to 0.40% silicon,
0.50 to 2.00% manganese, and
2.50 to 3.50% tungsten,
the balance, apart from unavoidable impurities, being iron.

2. A non-magnetic alloy according to claim 1, which consists, by weight, of:
27.4% nickel,
5.7% chromium,
0.7% carbon,
0.3% silicon,
1.9% manganese, and
3.5% tungsten,
the balance, apart from unavoidable impurities, being iron.

3. A watch balance spring made of a non-magnetic ferro-nickel-chromium alloy which consists by weight of:
26 to 29% nickel,
5 to 8.5% chromium,
together with one or more of the following
0.55 to 0.75% carbon,
0.20 to 0.40% silicon
0.50 to 2.00% manganese, and
2.50 to 3.50% tungsten,
the balance, apart from unavoidable impurities, being iron.

4. A non-magnetic ferro-nickel-chromium alloy according to claim 1, substantially as herein described.

5. A watch balance spring according to claim 3, substantially as herein described.

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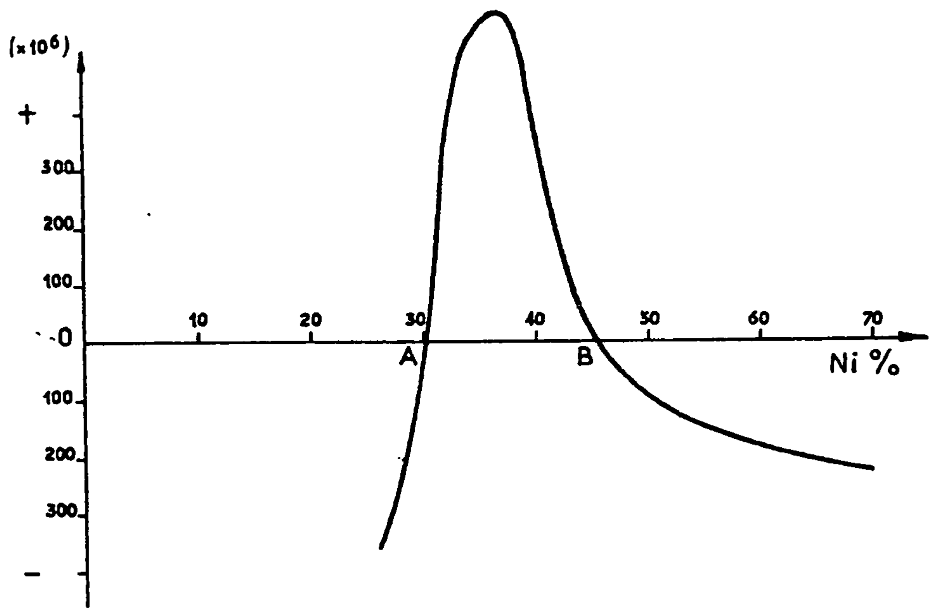
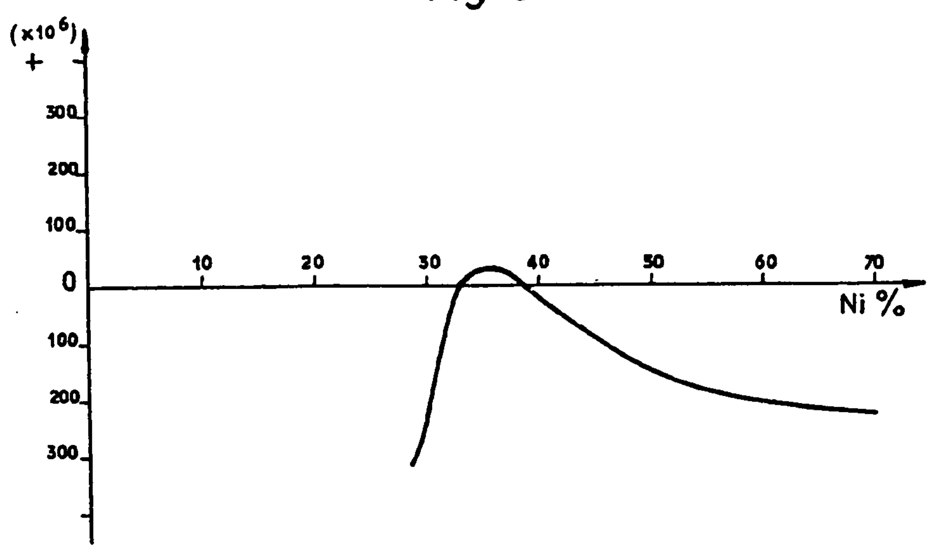
Fig.1



(×10⁶)
+
300
200
100
0
100
200
300
−
10
20
30
40
50
60
70
A
B
Ni %

Fig:3



(×10⁶)
+
300
200
100
0
100
200
300
10
20
30
40
50
60
70
Ni %

1,180,762 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig:2

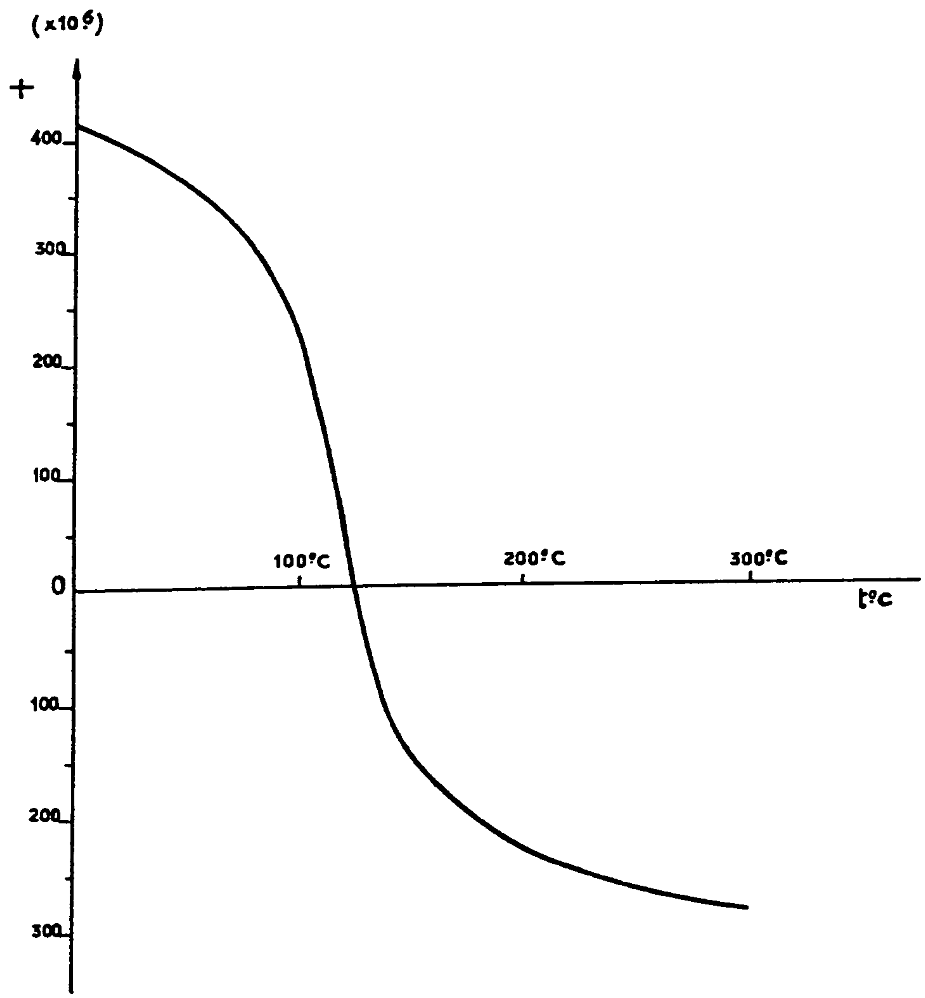


Fig. 1

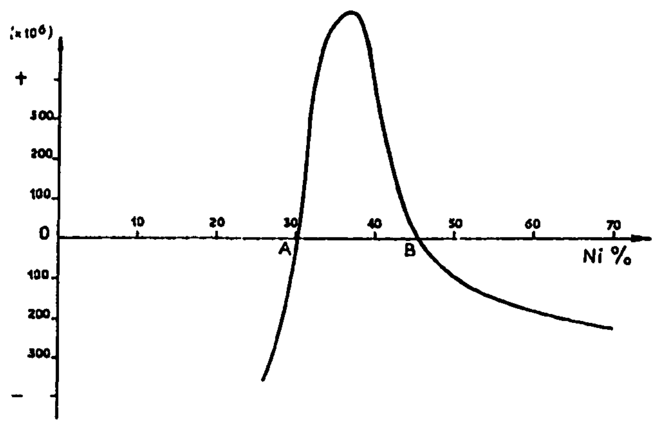


Fig. 3

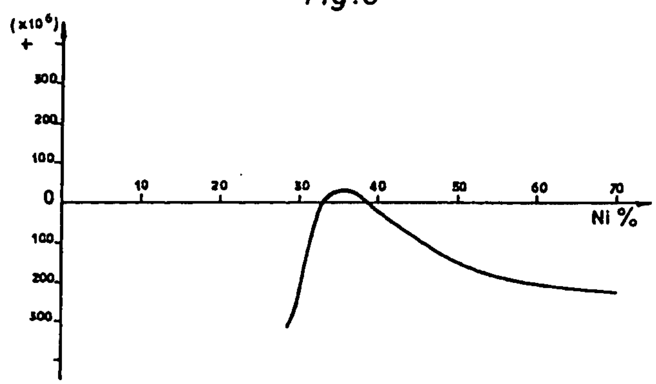


Fig. 2